Title: SYSTEM AND METHOD FOR REGULATION OF VEHICLES IN VEHICLE TRAINS

Abstract: The invention relates to a system for regulating vehicles in a vehicle train which comprises a leader vehicle and at least one further vehicle adapted to communicating via wireless communication. The system comprises a processor unit adapted to receiving data related to one or more vehicle parameters for a vehicle in the train or within an area around the train, to analysing said data according to predetermined criteria, to placing said vehicle in one of a predetermined number of categories based on the result said analysis, each of which categories has rules for how at least one vehicle in the train is to be regulated on the basis of the categorisation, to generating at least one control signal which indicates how one or more vehicles in the train are to be regulated on the basis of said categorisation and to sending the control signal to one or more control units on board one or more of the train's vehicles, which are then regulated accordingly. The invention relates also to a method for regulating vehicles in a vehicle train.
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System and method for regulation of vehicles in vehicle trains

Field of the invention
The present invention relates to techniques for vehicle trains and in particular to a system and a method for regulating vehicles in a vehicle train according to the preambles of the independent claims.

Background to the invention
The already high traffic volume on Europe's major roads is expected to increase still further. The energy required for carrying freight on these roads is also enormous and growing. A possible contribution to solving these problems is to have trucks travel close together in so-called vehicle trains ("platoons"). Travelling close together in a vehicle train considerably lowers the air resistance to trucks, reduces their energy requirements and uses the transport system more efficiently. Vehicle train means here a number of vehicles travelling with close spacing between them and as a unit. Studies have shown that the fuel consumption of a train's leading vehicle may be reduced by 2-10% and that of the following vehicle by 15-20%, as compared with a lone vehicle. These figures are based on the distance between the trucks being 8-16 metres and on travelling at 80 km/h. The lower fuel consumption means a corresponding reduction in CO$_2$ emissions.

These well-known facts are currently already being put to advantage by drivers, with consequently lowered traffic safety. A fundamental issue concerning vehicle trains is how to reduce the time gap between vehicles from a recommended 3 seconds to between 0.5 and 1 second without affecting traffic safety. The recommended time gap is currently based on

- driver reaction time
- delays in vehicle brake systems
- vehicle stopping distances

Driver reaction time can be eliminated by using distance sensors and cameras, ACC (adaptive cruise control) and LKA (lane keeping assistance) being examples of techniques already employed today. There is however a limitation in that distance sensors and cameras need a clear view of the target, making it difficult to detect what is happening
more than a couple of vehicles ahead in the queue. A further limitation is that they cannot react proactively, i.e. react to occurrences which have had no marked effect on the pace of traffic.

A development of IEEE standard 802.11 for WLAN (wireless local area networks) called 802.11p allows wireless transfer of information between vehicles, and between vehicles and infrastructures. Various kinds of information may be sent to and from the vehicles, e.g. vehicle parameters and strategies. A vehicle ahead in a train may thus for example

- send information about its own state, i.e. weight, speed, power output, location etc.,
- send information about forms of action which affect nearby traffic, e.g. braking,
- acting as a probe for vehicles behind by passing reports about traffic occurrences rearwards in the vehicle train.

This access to information makes it possible to create new functions, e.g. for helping drivers to drive more efficiently and more safely. The development of communication techniques has made it possible to design trucks and infrastructures which support the use of vehicle trains. A vehicle train can operate as a unit, thereby damping fluctuations in the train caused by speed changes and consequently allowing closer spacing and better overall traffic flow.

The creation of vehicle trains does however give rise to other kinds of problems. At present, not all vehicles are equipped for wireless communication, which means that a vehicle train may include vehicles which cannot communicate wirelessly. This may contribute to problems in regulating the train's vehicles in that not all of the necessary information is available.

"String-stable CACC design and experimental validation", R.P.A. Vugts, Master's Thesis, Technische Universiteit Eindhoven, Department of Mechanical Engineering, Control Systems Technology Group, describes the problem of one or more unknown vehicles moving into a vehicle train. However, the examination work does not cover these situations, as it confines itself to cases where communication with a vehicle immediately ahead is possible.
WO-2012/020297-A1 describes a control device and control method for regulation of vehicles. When a vehicle moves in between a host vehicle and a vehicle in front, the time between these two vehicles will be greater than the predetermined time. Radar is then used to detect the vehicle, and the time between the vehicles is set on the basis of the result of the detection.

For a vehicle train to work well the speed of the other vehicles has to be obtained via wireless communication. When a vehicle with no wireless communication facility moves into the train, it is not possible to obtain information wirelessly about its speed. Measures then have to be adopted to ensure correct regulation of the vehicles.

The object of the invention is therefore to propose an improved system which facilitates the regulation of vehicles which communicate in different ways.

**Summary of the invention**

In one aspect, the object described above is at least partly achieved by a system for regulating vehicles in a vehicle train according to the first independent claim. The train comprises a leader vehicle and at least one further vehicle adapted to communicating via wireless communication. The system further comprises a processor unit adapted to receiving data related to one or more vehicle parameters for a vehicle in the train or within an area around the train, and to analysing said data according to predetermined criteria. The processor unit is further adapted to placing said vehicles in one of a predetermined number of categories based on the result of said analysis, each of which categories has rules for how at least one vehicle in the train is to be regulated on the basis of the categorisation, and to generating at least one control signal which indicates how one or more vehicles in the train is to be regulated on the basis of said categorisation. The processor unit is then adapted to sending the control signal to one or more control units on board one or more of the train's vehicles, which are then regulated accordingly.

The invention facilitates the regulation of vehicles in a vehicle train. The information about which category vehicles belong to may be used by a regulator which can immediately adjust its calculation of control parameters for a vehicle in the train in
accordance with how nearby vehicles are categorised. The invention facilitates the regulation so as to continually maintain a safe distance from the vehicle in front irrespective of whether it is a known or unknown vehicle. Maintaining continually the shortest possible distance from vehicles in front results in both safe regulation and reduced fuel consumption.

In a second aspect, the object described above is at least partly achieved by a method for regulating vehicles in a vehicle train which comprises a leader vehicle and at least one further vehicle adapted to communicating via wireless communication. The method comprises the steps of i) receiving data related to one or more vehicle parameters for a vehicle in the train or within an area around the train, ii) analysing said data according to predetermined criteria, iii) placing said vehicles in one of a predetermined number of categories based on the result of said analysis, each of which categories has rules for how at least one vehicle in the train is to be regulated on the basis of the categorisation, and iv) regulating at least one vehicle in the train on the basis of said categorisation.

In a third aspect, the object described above is at least partly achieved by a computer programme product comprising programme instructions for enabling a computer system to perform steps according to the method described above and according to method steps in the detailed description when the programme instructions are run on the computer system.

Preferred embodiments are described in the dependent claims and in the detailed description.

Brief description of the attached drawings

The invention is described below with reference to the attached drawings, in which:

Figure 1 is a schematic diagram of a vehicle notation herein used for a vehicle train.

Figure 2 is a block diagram of the system for regulation of vehicles in a vehicle train according to an embodiment of the invention.

Figure 3 is a block diagram of the system for regulation of vehicles in a vehicle train according to another embodiment of the invention.
Figures 4A and 4B illustrate how an unknown vehicle may be categorised according to an embodiment of the invention.

Figure 5 is a schematic diagram of how centralised control works.

Figure 6 is a schematic diagram of how decentralised control works.

Figure 7 is a schematic diagram illustrating a method for regulating vehicles in a vehicle train according to an embodiment of the invention.

Detailed description of preferred embodiments of the invention

A vehicle train is defined as a number of vehicles working as a unit. The vehicles belonging to the train are each controlled automatically in the longitudinal direction and communicate with one another through a wireless network. Figure 1 is a schematic diagram of a vehicle notation herein used for a vehicle train. The host vehicle has the notation 1 and the vehicles in front the notation 2,...,N. The host vehicle may also be referred to as EGO and vehicle N as the leader vehicle. These notations are local for each vehicle in the train. The relative distance and speed between vehicle 1 and vehicle 2 are referred to as $d_{1,2}$, $v_{1,2}$ etc. Vehicle 1 has the speed $v_1$ etc. The general purpose of vehicle trains is to keep the vehicles as close to one another as possible by regulating their cruise controls and brake systems in order to take advantage of positive effects such as reduced air resistance.

By vehicle-to-vehicle communication (V2V communication), information may be obtained wirelessly from nearby vehicles. To this end, the vehicles are provided with units adapted to receiving and sending information wirelessly. A further way of communicating is via vehicle-to-infrastructure communication (V2I communication), whereby vehicles can exchange information wirelessly with, for example, roadside units with built-in intelligence.

Figure 2 is a block diagram of the system for regulation of vehicles in a vehicle train according to an embodiment of the invention. The system comprises a processor unit which may for example be on board one of the train's vehicles or in an externally located unit. In one embodiment each of the train's vehicles is provided with a processor unit according to the invention. It is implicit that the system also comprises memory space
connected to the processor unit, e.g. to store necessary data and instructions. The processor unit comprises also one or more processors which can execute machine code.

The processor unit is adapted to receiving data related to one or more vehicle parameters for a vehicle in the train or within an area around the train, meaning a range of the order of 0 to 2 km. The wireless communication has a range of up to about 2 km and radar has for example a range of between 50 and 200 m. If the processor unit is on board a vehicle, data may for example be obtained via a network on board. A usual network employed in vehicles is CAN (controller area network). Data on the network come from data sent wirelessly from other vehicles, and from sensors on board the host vehicle. The train's vehicles are usually equipped with a plurality of detectors which provide vehicle parameters such as the location and/or speed of the vehicles. Radar, lidar or a camera unit may for example provide information about the relative distance, the relative speed and/or the acceleration between the vehicles. The vehicles are then each provided with at least one radar unit, lidar unit and/or camera unit. GPS (global positioning system) is a satellite navigation system which gives the vehicle's location in coordinates of longitude and latitude and its speed to a GPS receiver on board. Each vehicle in the train preferably has a GPS unit. Information from the GPS unit may then be distributed to various systems on board the vehicle, e.g. via CAN, and to other vehicles via wireless communication. Information such as the engine's torque, the vehicle's weight, odometer data, direction and/or yaw rate is usually also readable from CAN. Information from CAN in one embodiment is read at a rate of 100 Hz.

Data transmitted wirelessly to the vehicle comprise not only vehicle parameters but also identification data indicating the vehicle or vehicles from which the vehicle parameters come. The processor unit is preferably adapted to using said identification data to monitor and keep track of which vehicles data come from. The wireless data take the form in Figure 2 of wireless signals represented by the broken lines ranging the processor unit. The signals contain data packets with associated identification indicating which vehicle the packet originates from. The rate at which the signals are received by the vehicles is for example 10 Hz. In one embodiment each vehicle has a specific ID number which is directly related to it and serves to identify a data packet. Each vehicle which forms part of
a train is also provided, in one embodiment, with a specific train ID, which may for example be the leader vehicle's ID number.

The processor unit is further adapted to analysing said data according to predetermined criteria, e.g. by estimation and/or sensor fusion, as will be explained below. On the basis of the result of the analysis, the vehicle is then placed in one of a predetermined number of categories which each have rules for how at least one of the train's vehicles is to be regulated on the basis of the categorisation. In one embodiment the predetermined categories comprise 1) wirelessly transmitting vehicles in the train and/or 2) wirelessly transmitting vehicles outside the train and/or 3) unknown vehicles in the train. In one embodiment said rules for a category indicate how a vehicle situated after a vehicle in the respective category is to be regulated. If a vehicle is placed in category 3), the vehicle after it in the train has in one embodiment to increase its distance from that vehicle to make it possible to achieve safe regulation. Other categories than those described above are of course also conceivable.

Figure 3 is a schematic diagram of a system for regulation of the vehicles in a vehicle train according to an embodiment of the invention. The processor unit comprises in this embodiment three function units, as will be explained below. This strategy is only to be regarded as an example, and other strategies are applicable within the context of the invention. The first unit, the "EST." unit, receives data from, for example, a network on board the vehicle. In one embodiment said data therefore comprise identification data indicating which vehicle said data come from. The processor unit may then be adapted to analysing the data from a vehicle by comparing identification data from received data with identification data for the vehicle train. On the basis of the result of the comparison, the vehicle is then placed in one of a predetermined number of categories. If identification data from received data match identification data from the vehicle train, the data received come from a wirelessly transmitting vehicle which is part of the train. The vehicle is then placed in category 1), i.e. wirelessly transmitting vehicle in the train. This makes it easy for the regulator to keep track of which vehicles are part of the train. If identification data from received data do not match identification data from the vehicle train, the received data come from a wirelessly transmitting vehicle which is outside the train. The vehicle is
then placed in category 2), i.e. wirelessly transmitting vehicle outside the train. It is appropriate to keep track of this category, since such a vehicle will perhaps wish to move into the train, in which case the system and the regulator will already know how it is to be regulated. In one embodiment states for one or more vehicles are also estimated in the EST. unit, and check values are calculated for each state. This estimation and calculation of check values may for example involve using an extended Kalman filter, as described below. Sensor data from known sources tagged with identification data are fusioned in order to estimate for example vehicle states in terms of the location, speed and direction of the vehicles. The EST. unit therefore receives monitored raw data and verifies inter alia that they are relevant for further estimations before they go into the next two units. The processor unit is therefore adapted to categorising vehicles at least partly on the basis of the method by which said data are produced, e.g. whether they are received wirelessly or not.

In the "FUSION" unit depicted in Figure 3, sensor values which are identifiable by marking, e.g. wireless data comprising identification data, are then fusioned with sensor data which are unmarked, e.g. data from radar, lidar or cameras. The fusion involves estimation of states, which in one embodiment comprise the location, speed and/or length of the train's vehicles which are to be covered by the regulation. An ID vector for all of the vehicles which are specified to be estimated is fed back in one embodiment to the EST. unit, as illustrated by "ID" in Figure 3. The ID vector comprises the identity of the vehicles which are specified to be estimated. The fusion may for example be conducted with an extended Kalman filter (EKF), as described below.

**Extended Kalman filter**

EKF is a filter which can handle non-linearities in models. The filtering involves a prediction step also called time update based on a physical model (1) of the vehicle, the previous information about states, and the sampling time. The vehicle model (1) depicted by way of example expresses the acceleration of vehicle i as
in which \( r_w \) is the vehicle's wheel radius, \( r_o \) the vehicle's wheel inertia, \( m \) the vehicle's weight, \( i_t \) the vehicle's transmission ratio of current gear, \( i_f \) the vehicle's transmission ratio for the final gear, \( \eta_t \) an efficiency constant for current gear, \( \eta_f \) an efficiency constant for the final gear, \( J_e \) the engine's moment of inertia, \( T_e \) the engine torque, \( c_d \) the air draught coefficient, \( A_a \) the vehicle's front cross-sectional area, \( p_a \) the air density, \( v \) the vehicle's speed, \( f_i(d) \) a function for vehicle i's reduction of the air draught coefficient, \( c_r \) the vehicle's rolling coefficient, \( g \) the gravitational constant and \( \alpha \) the gradient of the road. The model is then discretised in order to be usable in the estimation. The description of EKF set out below uses for the sake of simplicity a general model (2) for the vehicle's movement, which may therefore be matched by a discretised variant of model (1).

A general model of a non-linear movement model in discrete time is represented by

\[
\hat{x}_{k+1} = f(\hat{x}_k, u_k, \Theta, v_k)
\]  

(2)
in which \( \hat{x}_k \) is the estimated state vector, \( u_k \) input signals, \( \Theta \) model parameters and \( v_k \) process noise. The time update involves predicting states (3) and the associated covariance (4) as

\[
\hat{\sigma}_{\text{state}} = f(\hat{x}_{k-1}, u_{k-1}, \Theta, v_{k-1})
\]  

(3)

\[
P_{k|k-1} = F_k P_{k|k-1} F_k^T + Q_k
\]  

(4)
in which

\[
F_{k-1} = \frac{\partial f}{\partial x} |_{\hat{x}_{k-1}, u_{k-1}}
\]  

(5)
and $Q_k$ is the covariance matrix for $v_k$. Thus $Q_k$ describes the model’s uncertainty and may be weighted according to how well the model corresponds to reality.

The next step is to compare the predicted states with measured values for them, a step also called measurement update. This comparison involves using a model for the measured values according to

$$y_k = h(\hat{x}_k, u_k, \theta, e_k)$$

in which $y_k$ represents the now pre-processed measured values in vector format and $e_k$ the measuring noise. The measurement update then involves comparing the pre-processed measured values with the estimated state vector from the time update according to

$$\varepsilon_k = y_k - h(\hat{x}_{k|k-1})$$

The covariance $S_k$ for the measured value residual $\varepsilon_k$ is calculated as

$$S_k = H_k P_{k|k-1} H_k^T + R_k$$

in which $P_k$ is the covariance for states, $H_k$ is calculated as

$$H_k = \frac{\partial h}{\partial x} |_{\tilde{x}_{k|k-1}}$$

and $R_k$ is the covariance matrix for the measuring noise $e_k$. $R_k$ is the corresponding weight matrix to $Q_k$ and is adjustable according to the uncertainty of the sensor measured values. The estimated state update $\hat{x}_k$ is then calculated as

$$\hat{x}_{k|k} = \hat{x}_{k|k-1} + K_k \varepsilon_k$$

in which the Kalman amplification $K$ is

$$K_k = P_{k|k-1} H_k^T S_k^{-1}$$
The covariance matrix $P$ for the estimated states is updated as

$$P_{k|k} = (I - K_k H_k) P_{k|k-1}$$  \hfill (12)

The input signals to the filter which are used in the FUSION unit comprise the vector

$$w_{fe} = \begin{bmatrix} T_e & \Phi & \alpha \end{bmatrix}^T$$  \hfill (13)

in which $T_e$ (the vehicle’s engine torque), $\Phi$ (the vehicle’s direction) and $\alpha$ (road gradient) are obtained from data via wireless communication.

The measurements therefore come from two different sources. The first source is the EST. unit, which gives an estimated location $z_p$ and speed $z_v$ for each vehicle, e.g. on the basis of sensor measurements from the host vehicle and wireless data. The second source is here radar, which provides a relative distance $z_{p_{rel}}$ and a relative speed $z_{V_{rel}}$ relative to the vehicle in front. The measurement signals to the filter represent the vector (14) which may then be expressed as

$$Z_k = \begin{bmatrix} z & z_{V_{rel}} & z_{p_{rel}} & z_{V_{rel}}Y \end{bmatrix}$$  \hfill (14)

The calculations in EKF may then be conducted either on the basis of a global reference system which covers all of the train’s vehicles and uses GPS coordinates in the form of longitude and latitude to describe the locations of the vehicles, or a local reference system arrived at by coordinate transformation of the global coordinate system. In the local reference system the host vehicle EGO is the origin. Depending on which reference system is used, measurement equations $h(\hat{z})$ may be expressed for respective $z$ parameters and are then used in the filtering.

In the estimation in the FUSION unit it is possible to estimate for example the vehicle’s length, which may be usable data for many applications. As the length of trucks often
changes, depending on how many trailers they have and how long the trailers are, matters are facilitated if the length can be calculated instead of being determined beforehand. The processor unit in one embodiment is adapted to analysing data by estimating the vehicle’s length \( l \), calculating a difference \( \Delta l \) between the estimated length and a predetermined length of the vehicle, and comparing \( \Delta l \) with a predetermined threshold value. The vehicle may then be placed in a category on the basis of the result of the comparison. If the estimated length of the vehicle train increases suddenly or at least by more than the threshold value, this indicates that an unknown vehicle has moved into the train. This unknown vehicle may then be placed in category 3), i.e. unknown vehicle in the train. The unknown vehicle then does not send data wirelessly, and a system on board a vehicle which needs to identify a vehicle ahead via radar and wireless data will receive data which originates from different vehicles. Figures 4A and 4B exemplify how an unknown vehicle can be identified by monitoring the length of vehicle \( i \) in front. The respective locations of vehicles \( i \) and \( i-1 \) are known from GPS and the relative distance \( \Delta \rho - \text{GPS} \) between the vehicles may then be calculated. Vehicle \( i-1 \) uses radar to measure the relative distance \( \Delta \rho_{rel} \). The FUSION unit determines whether the measurements pertain to the same vehicle. The length \( l_i \) of vehicle \( i \) may then be determined by subtracting \( \Delta \rho_{rel} \) from \( \Delta \rho - \text{GPS} \), as illustrated in Figure 4A. This length is then assumed to be the vehicle’s actual length and may therefore be determined while it is in motion. This now predetermined length is then preferably compared continuously with new calculated values for the length \( l_i \) of vehicle \( i \). A difference may be calculated and if it is greater than a predetermined threshold value it is assumed that another vehicle has moved in between vehicles \( i \) and \( i-1 \), as illustrated in Figure 4B. The intruding vehicle is then placed in category 3) as previously explained. In one embodiment the predetermined threshold value is between 5 and 50 m.

The processor unit may also be adapted to calculating one or more check values for said estimated states to indicate how reliable the estimation of the state or states is, depending on how well data from different sources match. If the length of a vehicle suddenly increases, the check value in the form of the variance of the estimated length will also increase, indicating that an unknown vehicle has moved in between vehicles \( i \) and \( i-1 \) (see Figure 4B). A vehicle may thus be characterised on the basis of the variance of its states.
In this embodiment the processor unit is therefore adapted to analysing the data by calculating the variance of the vehicle's length \( l_i \), comparing the variance with a predetermined threshold value and placing the vehicle in a category on the basis of the result of the comparison. This knowledge may then be used in the regulation of the train's vehicles in order to achieve safer regulation.

In the embodiment depicted in Figure 3, the "REG." unit then receives the relative distances \( d_{k,k+1} \) between the N vehicles and the speed \( v_k \) of each of the train's vehicles from the FUSION unit. The categories of the vehicles are also passed on the REG. unit, which then adapts its regulating strategy according to the categorisation. In the category example described above, the REG unit takes account of the vehicles which have been placed in categories 1) and 3) and adjusts for example their speed \( v \) and the distances \( d \) between them accordingly. The processor unit is therefore adapted to generating at least one control signal which indicates how the vehicle's vehicles is to be regulated on the basis of said categorisation. In one embodiment control signals are generated by using an MPC algorithm as explained below.

MPC
MPC is an extension of an LQ regulator and is often used for solving multi-variable regulating problems. The LQ regulator minimises a cost function which is described as a linear differential equation. The general quadratic cost function is minimised with respect to the control signal \( u \), e.g. the distance \( d \) and/or speed \( v \), as

\[
ml_n \sum_{j=0}^{\infty} \| x(k+j) \|_2^2 + \| u(k+j) \|_2^2
\]  
(15)

in which \( P_1 \) and \( P_2 \) are weight matrices and are used to balance how states and the control signal are assessed. MPC may also handle limitations of the control signal and states, in which case the cost function to be analysed becomes

\[
J_{u_p}(x(k)) = \sum_{j=0}^{p-1} \| x(k+j) \|_2^2 + \| u(k+j) \|_2^2
\]  
(16)
in which \( H_p \) is the prediction horizon, and limitations of the spacing between the train's vehicles, their speed and/or engine torque. One embodiment introduces an integrating action in the cost function (13) whereby the difference between two consecutive control signals is minimised. This embodiment results in more uniform regulation in that the control signal is not allowed to vary too much. Output signals from the MPC comprise control signals to other regulators on board the vehicle in the form of a reference speed to the cruise control and/or a reference retardation to the brake system. The regulator will therefore serve as a superordinate regulator over the existing cruise controls and/or brake systems. In one embodiment the system comprises a conversion unit (not depicted) adapted to converting a control signal comprising torque \( T_e \) to a suitable control signal for a control unit of a vehicle. The conditions within which this may take place are

\[
T_e > -250, \quad v_{ref} = v(k + 1) \quad (17)
\]

\[
T_e \leq -250, \quad a_{ref} = \frac{v(k+1)-v(k)}{\tau_s} \quad (18)
\]

where \( v_{ref} \) is input signal to a cruise control and \( a_{ref} \) input signal to a brake system. The values indicated are only to be regarded as examples, and other values are therefore applicable for the invention. Control signals are then sent on from the REG. unit to one or more control units of the vehicle or to control units of other vehicles, depending inter alia on choice of regulating strategy. Figure 5 is a schematic diagram of how centralised control works for N vehicles in a vehicle train. The boundary frame signifies that all of the vehicles have information about all the other vehicles in the train. Each vehicle then solves the same optimisation problem. In other words, each of the train's vehicles calculates an optimum control signal for each vehicle in the train. Fusion and distribution of the optimum control signals are then required to achieve a control signal which becomes the actual output signal from the regulator to each control unit of the respective vehicles. Figure 6 is a schematic diagram of how decentralised control works. The boundary frames signify that each vehicle has a description of its own vehicle system and conducts optimisation of its own control signal(s), so the control signal or signals may be used immediately after having been calculated.
The invention relates also to a method for regulation of vehicles in a vehicle train which comprises a leader vehicle and at least one further vehicle adapted to communicating via wireless communication. The method is illustrated by the flowchart in Figure 7 and comprises a first step i) of receiving data related to one or more vehicle parameters for a vehicle in the train or within an area around the train. These data may for example be obtained via wireless communication and/or sensor systems, e.g. GPS on board the vehicle. As a second step ii), the data are analysed according to predetermined criteria. In one embodiment the data comprise identification data which indicate which vehicle said data come from, in which case the method comprises analysing said data from a vehicle by comparing identification data from received data with identification data for the vehicle train. This makes it possible to identify whether the vehicle belongs to the vehicle train or not and whether it is a transmitting vehicle, i.e. a vehicle which transmits data wirelessly. As a third step iii) the result of the analysis serves as a basis for placing the vehicles in one of a predetermined number of categories which each have rules for how at least one of the train's vehicles is to be regulated on the basis of the categorisation. The rule or rules for a category indicate for example how a vehicle situated after a vehicle in the respective category is to be regulated. In another embodiment, step ii) comprises analysing the data by estimating the vehicle's length \( l \), calculating a difference \( \Delta l \) between the estimated length and a predetermined length and comparing \( \Delta l \) with a predetermined threshold value, and step iv) comprises categorising the vehicle on the basis of the result of the comparison. As a fourth step iv) at least one of the train's vehicles is regulated on the basis of the categorisation.

The invention relates also to a computer programme product comprising computer programme instructions for enabling a computer system to perform steps according to the method described above when the programme instructions are run on said computer system. In one embodiment the instructions are stored on a medium which can be read by a computer system.

The present invention is not restricted to the embodiments described above. Sundry alternatives, modifications and equivalents may be used. The aforesaid embodiments therefore do not limit the invention's scope, which is defined by the attached claims.
Claims

1. A system for regulating vehicles in a vehicle train which comprises a leader vehicle and at least one further vehicle adapted to communicating via wireless communication, which system comprises a processor unit adapted to
   - receiving data related to one or more vehicle parameters for a vehicle in the train or within an area around the train,
   - analysing said data according to predetermined criteria,
   - placing said vehicle in one of a predetermined number of categories based on the result of said analysis, each of which categories has rules for how at least one vehicle in the train is to be regulated on the basis of the categorisation,
   - generating at least one control signal which indicates how one or more vehicles in the train are to be regulated on the basis of said categorisation
   - sending the control signal to one or more control units on board one or more of the train's vehicles, which are then regulated accordingly.

2. A system according to claim 1, which comprises categorising vehicles at least partly on the basis of the method by which said data are produced.

3. A system according to claim 1 or 2, in which said data comprise identification data which indicate which vehicle said data come from and the processor unit is adapted to analysing said data from a vehicle by comparing identification data from received data with identification data for the vehicle train.

4. A system according to any one of the above claims, in which the processor unit is adapted to analysing said data by estimating the vehicle's length \( l \), calculating a difference \( \Delta l \) between the estimated length and a predetermined length, comparing \( \Delta l \) with a predetermined threshold value and placing the vehicle in a category on the basis of the result of the comparison.
5. A system according to any one of the above claims, in which said rules for a category indicate how a vehicle situated after a vehicle in the respective category is to be regulated.

6. A system according to any one of the above claims, in which said predetermined categories comprise wirelessly transmitting vehicles in the train and/or wirelessly transmitting vehicles outside the train and/or unknown vehicles in the train.

7. A system according to any one of the above claims, in which said data comprise wirelessly transmitted signals.

8. A system according to any one of the above claims, in which said data comprise data received via radar, camera and/or GPS (global positioning system).

9. A method for regulating vehicles in a vehicle train which comprises a leader vehicle and at least one further vehicle adapted to communicating via wireless communication, which method comprises the steps of

- receiving data related to one or more vehicle parameters for a vehicle in the train or within an area around the train,

- analysing said data according to predetermined criteria,

- placing said vehicles in one of a predetermined number of categories based on the result of said analysis, each of which categories has rules for how at least one vehicle in the train is to be regulated on the basis of the categorisation,

- regulating at least one of the train's vehicles on the basis of said categorisation.

10. A method according to claim 9, which comprises categorising vehicles at least partly on the basis of the method by which said data are produced.

11. A method according to claim 9 or 10, in which said data comprise identification data which indicate which vehicle said data come from, which method
comprises analysing said data from a vehicle by comparing identification data from received data with identification data for the vehicle train.

12. A method according to any one of claims 9 to 11, comprising analysing said data by estimating the vehicle's length $l$, calculating a difference $\Delta l$ between the estimated length and a predetermined length, comparing $\Delta l$ with a predetermined threshold value and categorising the vehicle on the basis of the result of the comparison.

13. A method according to any one of claims 9 to 12, in which said rules for a category indicate how a vehicle situated after a vehicle in the respective category is to be regulated.

14. A method according to any one of claims 9 to 3, in which said predetermined categories comprise wirelessly transmitting vehicles in the train and/or wirelessly transmitting vehicles outside the train and/or unknown vehicles in the train.

15. A computer programme product comprising computer programme instructions for enabling a computer system to perform steps of the method according to any one of claims 9 to 14 when the programme instructions are run on said computer system.

16. A computer programme product according to claim 15, in which the programme instructions are stored on a medium which can be read by a computer system.
FIG. 3

FIG. 4A

FIG. 4B
RECEIVE DATA FOR A VEHICLE

ANALYSE SAID DATA

CATEGORISE SAID VEHICLE

REGULATE VEHICLE ON BASIS OF CATEGORISATION

FIG. 7
**INTERNATIONAL SEARCH REPORT**

**International application No.**
PCT/SE2013/050672

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**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC: see extra sheet**

According to International Patent Classification (IPC) or to both national classification and IPC

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**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC: B60W, B61 L, G05D, G08G**

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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[ ] Further documents are listed in the continuation of Box C.  
[ ] See patent family annex.

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**Date of the actual completion of the international search**

18-1 1-201 3

**Date of mailing of the international search report**

19-1 1-201 3

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